Developing a framework for assessing the impact of geothermal development phases on ecosystem services

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Abstract. The 2014 Indonesian National Energy Policy has set a target to provide national primary energy usage reached 2.500 kWh per capita in the year 2025 and reached 7.000 kWh in the year 2050. The National Energy Policy state that the development of energy should consider the balance of energy economic values, energy supply security, and the conservation of the environment. This has led to the prioritization of renewable energy sources. Geothermal energy a renewable energy source that produces low carbon emissions and is widely available in Indonesia due to the country's location in the "volcanic arc". The development of geothermal energy faces several problems related to its potential locations in Indonesia. The potential sites for geothermal energy are mostly located in the volcanic landscapes that have a high hazard risk and are often designated protected areas. Local community low knowledge of geothermal use also a challenge for geothermal development where sometimes strong local culture stand in the way. Each phase of geothermal energy development (exploration, construction, operation and maintenance, and decommissioning) will have an impact on the landscape and everyone living in it. Meanwhile, natural and other human-induced drivers will keep landscapes and environments changing. This conference paper addresses the development of an integrated assessment to spatially measure the impact of geothermal energy development phases on ecosystem services. Listing the effects on the ecosystem services induced by each geothermal development phases and estimating the spatial impact using Geographic Information System (GIS) will result in an overview on where and how much each geothermal development phase affects the ecosystem and how this information could be included to improve national spatial planning.

1. Introduction

Geothermal energy a renewable energy source only can be generated in certain areas. Collisions between tectonic plates form a subduction zone which changes the dense material into buoyant magma which rises through earth surface forming a "volcanic arc" along the subduction zone. Through volcanoes, earth heat source becomes closer to the surface and becomes potential for geothermal energy extraction [1,2]. Geothermal power plants have very low gaseous emissions to the air when compared with all other power generation technologies that emit CO_2 as a normal part of the operation [3]. Geothermal energy potential is widely available in Indonesia due to the country's location in the "volcanic arc".

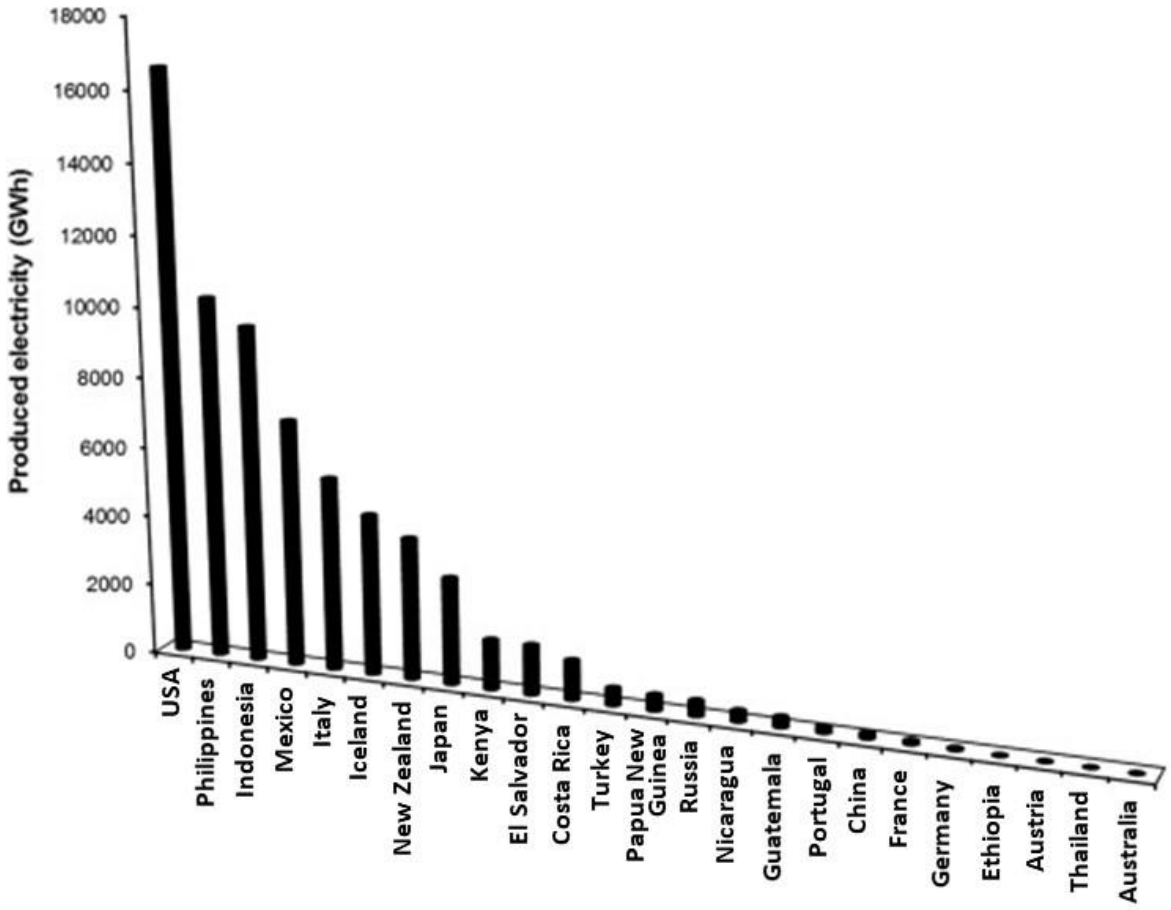

Figure 1. Generated electricity (GWh) from geothermal power plants in 2010 (Bayer et al. 2013)

USA, Philippines, Indonesia, Mexico, Italy, Iceland, New Zealand, and Japan produce more than 90% of the world's geothermal energy [4] (see figure 1.). The Indonesian National Energy Policy has set a target to provide national primary energy usage reached 2.500 kWh per capita in the year 2025 and reached 7.000 kWh in the year 2050 [5]. The growing environmental concerns combined with finite availability call into question the sustainability of an energy strategy based almost exclusively on fossil fuel [6]. 40% of the world's geothermal energy potential is located in Indonesia, and it's a very potential renewable energy in Indonesia to be explored [7,8]. Many technological, economic and environmental aspects of geothermal plants are fundamentally controlled by geological and local factors which make environmental assessment of geothermal development is site specific. These conditions raise the needs to develop geothermal energy as a renewable energy source for electricity in Indonesia.

This conference paper aim is to propose an integrated assessment framework and indicators to measure the impact of geothermal energy development phases on ecosystem services at different national levels.

2. Environmental Impact Assessment of Geothermal Development

Development impacts are often assessed through an environmental impact assessments. Environmental assessment is a process to assess the positive and negative consequences of an activity to the environment. There are two types of environmental assessment, Environmental Impact Assessment (EIA) is applied to project activity level and Strategic Environmental Assessment (SEA) is applied to

plan, policy, and program. Environmental Impact Assessment firstly introduced in 1969 and has been tools for decision making until present day, also for geothermal energy project such as in Italy [9,10], Iceland [11], Greece [12], China [13,14], and Indonesia [15].

Geothermal power plants have components, each of which has an influence on the surrounding environment such as production/reinjection boreholes, connecting/delivery pipes, silencers, powerhouse and cooling towers. The effect on the environment varies, some of them only temporarily (during construction or demolition), some of them lasted with power plants operation (e.g. noise nuisance) [4]. Geothermal development phase generally divided into four phases and each phase will give different impact to the environment:

1. Resource exploration and drilling
2. Construction
3. Operation and Maintenance
4. Decommissioning and Site Rehabilitation

The U.S. Department of the Interior through The Tribal Energy and Environmental Information Clearinghouse website (https://teeic.indianaffairs.gov/er/geothermal/impact/index.htm) [16], Bayer et al. [4], and DiPippo [3]. Table 1 shows that the potential environmental impacts from geothermal development phase varies. The environmental impact depends on the type and size of the power plant, the location of facilities with respect to other resources, the number of wells, and drilling technology used.

Table 1. Potential environmental impact of geothermal development phase activity

Potential Impact	**Geothermal Development Phase**			
	Resource Exploration and Drilling	Construct-ion	Operations and Maintenance	Decommissioning and Site Reclamation
Acoustics/Noise [3,4,16]	Yes	Yes	Yes	Yes
Air Quality [4,16]	Yes	Yes	Yes	Yes
Cultural Resources [4,16]	Yes	Yes	Yes	No
Ecological Resources [3,4,16]	Yes	Yes	Yes	No
Environmental Justice [4,16]	No	Yes	Yes	Yes
Hazardous Materials and Waste Management [3,4,16]	Yes	Yes	Yes	Yes
Health and Safety [3,16]	Yes	Yes	Yes	Yes
Land Use [4,16]	Yes	Yes	Yes	Yes
Paleontological Resources [16]	Yes	Yes	Yes	Yes
Socioeconomics [4,16]	Yes	Yes	Yes	Yes
Soils and Geologic Resources [3,16]	Yes	Yes	No	Yes
Transportation [16]	No	Yes	No	Yes
Visual Resources [3,4,16]	No	Yes	Yes	No

Water Resources (Surface Water and Groundwater) [3,4,16]	Yes	Yes	Yes	Yes
Geological Hazards [3,4]	Yes	Yes	Yes	No

All three reference agreed that geothermal development will give impact related to noise nuisance, ecological resources, waste management, visual resources, and water resources. Although indicators from TEEIC tends to be more detailed compared with Bayer et al. [4] and DiPippo [3], but it does not measure the geological hazards that can be caused by geothermal development activity such as landslide, induced seismicity, and disturbance of hydrothermal manifestations. Meanwhile, DiPippo [3] list of geothermal challenge only focused on ecological point of view and did not consider social-economic-cultural values. Assessment method that combines ecological and socio-economic-cultural concepts are needed to gain a comprehensive overview of the geothermal impact and the impacted.

EIA in Indonesia has become an obligation for every environmental affecting project since the implementation Government Regulation No. 29, 1986. The regulation was replaced by Government Regulation No. 27 Year 1999 and had a second replacement by Government Regulation No. 27 in 2012 with has some addition in environmental permit. EIA guidelines from the Indonesian Ministry of Environment include a comprehensive assessment by combining ecology, socio-economy-culture, and public health aspects [17]. The regulations also put monitoring and evaluation as a reference for project implementations so every environmental impacted activity can be justified. In general, EIA in Indonesia already has a good foundation to assess the impact of the certain project to the environment.

Indonesia EIA practice has not applied optimal public participation as an input in the environmental assessment. This triggers a conflict in society just as happened in Sarulla geothermal field in 2008 [18] and Bali [19] where local communities opposed geothermal development because of lack public participation as screening process of local needs and values related to the environment. Common assessment practice for decision making process often only involving limited actors and mostly using silo based approach and does not integrate between sectors.

3. Ecosystem Services and Participatory Mapping of Geothermal Development

Potential environment impact of geothermal development (see Table 1) are spatial phenomena. Maps in EIA documents are compulsory but are typically only used as a base map showing general spatial information instead of using it as visualization of impact. To identify suitable locations for a geothermal facility is done by identifying locations where the benefits outweigh the conflicts/negative environmental impact.

Baker et al. [20] listed ecosystem services strength that could address the gap in environmental assessment:

1. Ecosystem services is an integrating concept which instead of dealing with environmental properties as an individual but a service that flow from the environment to human well-being and back to the environment.
2. Ecosystem services moved the perspective from environmental properties to environmental benefit.
3. Ecosystem service engage stakeholders as assessment indicators.
4. Ecosystem services may be of particular value where there are clear conflicts between traditional environmental, economic arguments and different spatial level decision making.
5. The ecosystem service framing makes explicit the value of the environment for decision makers.

Ecosystem services approach is an early attempt at outlining how decision makers can take practical steps to restore the health of ecosystem services and make development more sustainable.

Figure 2 shows the main elements of the proposed framework: the driving forces, ecosystem, service provision, human well-being, and societal response. The framework development is based on general Driver, Pressure, State, Impact, Response (DPSIR) framework where geothermal development becomes the main driving force that will affect the ecosystem properties, function, and services.

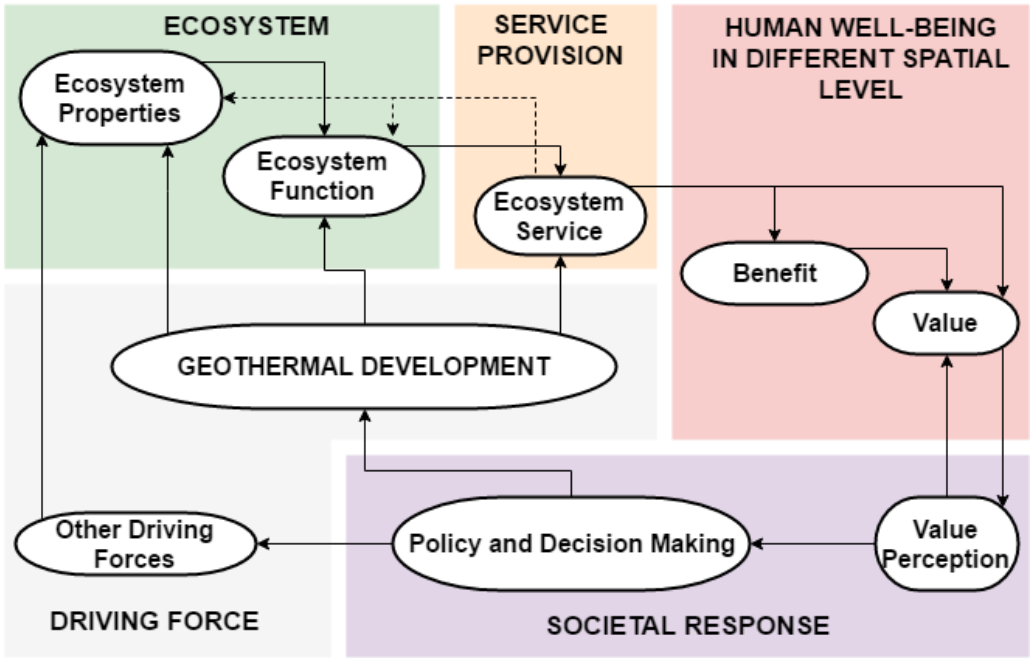

Figure 2. Framework for assessing links between land management, ecosystem services provision, and human well-being (modified from van Oudenhoven et al. [21]). Solid arrows indicate effects; dashed arrows indicate feedbacks

Spatial assessment of geothermal development impacts such as noise, air quality, ecological resource, waste, land use change, geologic resources, and water resources will provide information on how big is the affected areas. As an example, Cai et al. [22] and Farcas & Sivertun [23] able to map the range of noise impact that can be used for mapping the areas impacted from geothermal development phase especially for drilling, construction, and power plant disassembling activity where the noise effect is at the loudest. Spatial analysis can provide information and perspective that cannot be supplied by other analysis [24].

Social-economic-cultural issues of geothermal development are a challenge for EIA of geothermal development in Indonesia because of the different culture and local characteristics throughout the country. Different culture will determine the way of decision making. The public participatory process already is compulsory in Indonesia EIA regulation. Combining public participatory with spatial knowledge will provide richer information about ecosystem services and understand how communities utilize the environment in geothermal proposed area. Brown and Fagerholm [25] reviewed PPGIS/PGIS approaches for mapping ecosystem services. They identify that there are two approaches to measures and quantify ecosystem services in traditional economic values. The first approach is to reveal the importance of natural systems and assets that provide long-term human benefit vis-à-vis. The second approach is to focus on place-based valuation of services in non-monetary terms to provide spatially-explicit guidance for future land use decisions.

Decision making processes do not only need to be integrated between sectors but also need to be integrated between local and national policies. Garcia-Nieto et al. [26] presented that participatory mapping process becomes a powerful method in identifying Service Providing Unit's (SPU's) and Service Benefiting Areas (SBA's) spatially. In some ecosystem services, different stakeholders also show different perspectives related to SBA's spatial scale. Multi stakeholder approach for decision making also was used by Llopis-Albert et al. [27] to facilitate and engage stakeholders participation in the water resources management in Spain.

4. Working Progress

This review identified that spatial analysis is not yet optimal in the EIA process in Indonesia. Visualization of impacts through maps in different scale will help to identify the high and low impacted stakeholders. From a valuation perspective, environmental problems and conflicts originate from trade-offs between values. The urgency and importance to integrate nature's diverse values in decisions and actions stand out more than ever [28]. Ecosystem services mapping will able to identify specific assets of nature that affected by geothermal development.

Ecosystem services approach can explore how current and future trends in the condition of these services will affect geothermal development goals. The findings of this presentation will address the gap between EIA regulation and EIA practice for geothermal development projects in Indonesia and serve as inputs for future research in developing spatial decision support system for geothermal field landscape management. Decision maker can build partnerships across institutional and political boundaries to address the risks and opportunities for ecosystem services that presents caused by environmental affected project.

5. Acknowledgement

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